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Antimicrobial prescriptions and adherence to prudent use guidelines for selected canine diseases in Switzerland in 2016

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Abstract: Background: Antimicrobial resistance is an increasing problem in human and veterinary medicine and is closely linked to the use of antimicrobials. The objective of this study was to describe antimicrobial prescriptions for selected canine diseases in Switzerland during 2016. Methods: Dogs presented to two university hospitals and 14 private practices for acute diarrhoea (AD; n=371), suspected or confirmed urinary tract infections (UTIs; n=245), respiratory tract infections (RTIs; n=274) or wound infections (WIs; n=175) were included. Clinical history, diagnostic work-up and antimicrobial prescription (class, dosage and duration) were retrospectively assessed. A justification score was applied to evaluate appropriateness of antimicrobial therapy based on available national and international consensus guidelines. Results: Antimicrobials were prescribed in 65 per cent of dogs with AD, 88 per cent with UTI, 62 per cent with RTI and 90 per cent with WI. The most prescribed antimicrobial classes (monotherapy and combination therapy) were potentiated aminopenicillins (59 per cent), nitroimidazoles (22 per cent), non-potentiated aminopenicillins (16 per cent) and fluoroquinolones (13 per cent). Overall, 38 per cent (95 per cent CI 0.35 to 0.41) of the prescriptions were in accordance with consensus guidelines. In dogs with AD, antimicrobial therapy was associated with the presence of haemorrhagic diarrhoea ($P < 0.05$) and complied in 32 per cent with consensus guidelines, which recommend antimicrobial treatment only when sepsis is suspected. A bacterial aetiology was confirmed via culture and/or sediment examination in 36 per cent of dogs with suspected UTI. Conclusions: Overall, adherence to consensus guidelines was poor both, at university hospitals and private practices. Antimicrobial stewardship measures are therefore needed to improve prudent use.

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Antimicrobial prescriptions and adherence to prudent use guidelines for selected canine diseases in Switzerland in 2016

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ABSTRACT

Background Antimicrobial resistance is an increasing problem in human and veterinary medicine and is closely linked to the use of antimicrobials. The objective of this study was to describe antimicrobial prescriptions for selected canine diseases in Switzerland during 2016. **Methods** Dogs presented to two university hospitals and 14 private practices for acute diarrhoea (AD; n=371), suspected or confirmed urinary tract infections (UTIs; n=245), respiratory tract infections (RTIs; n=274) or wound infections (WIs; n=175) were included. Clinical history, diagnostic work-up and antimicrobial prescription (class, dosage and duration) were retrospectively assessed. A justification score was applied to evaluate appropriateness of antimicrobial therapy based on available national and international consensus guidelines.

Results Antimicrobials were prescribed in 65 per cent of dogs with AD, 88 per cent with UTI, 62 per cent with RTI and 90 per cent with WI. The most prescribed antimicrobial classes (monotherapy and combination therapy) were potentiated aminopenicillins (59 per cent), nitroimidazoles (22 per cent), non-potentiated aminopenicillins (16 per cent) and fluoroquinolones (13 per cent). Overall, 38 per cent (95 per cent CI 0.35 to 0.41) of the prescriptions were in accordance with consensus guidelines. In dogs with AD, antimicrobial therapy was associated with the presence of haemorrhagic diarrhoea ($P<0.05$) and complied in 32 per cent with consensus guidelines, which recommend antimicrobial treatment only when sepsis is suspected. A bacterial aetiology was confirmed via culture and/or sediment examination in 36 per cent of dogs with suspected UTI.

Conclusions Overall, adherence to consensus guidelines was poor both, at university hospitals and private practices. Antimicrobial stewardship measures are therefore needed to improve prudent use.

INTRODUCTION

Antimicrobials are vital to modern medicine, and antimicrobial resistance is a global, urgent threat to human and animal health. The development of antimicrobial resistance is unambiguously linked to exposure of bacteria to antimicrobials.¹ Dogs and cats are

considered family members in many households and benefit from advanced medical care, which often includes hospitalisation and treatments with broad-acting antimicrobials, many of them being of critical importance to human medicine. The selection pressure put on bacterial populations via the administration of antimicrobials favours the selection of multidrug-resistant organisms (MDROs) such as methicillin-resistant *Staphylococcus pseudintermedius* and extended-spectrum beta-lactamase producing *Escherichia coli*.^{2–5} Small animal medicine therefore likely plays a significant role in the selection and dissemination of MDROs. To foster the prudent use of antimicrobials, guidelines have been created in both human and veterinary medicine.^{6–9}

Antimicrobial prescribing habits by small animal veterinarians have been reported from a number of countries including the USA,¹⁰ Australia,¹¹ Belgium,¹² UK,¹³ Finland,¹⁴ Denmark¹⁵ and Italy.¹⁶ Such studies are either designed as surveys using fictional case scenarios,^{11–13 16} or based on data extracted from pharmacy or patient records.^{13 14 17–23} Patterns of antimicrobial use for selected diseases in cats in Switzerland have recently been published.²⁴ The results of these studies indicate that overprescription of antimicrobials including critically important antimicrobials and non-adherence to guidelines is common in small animal medicine but varies considerably between countries. In Europe, a north-to-south and a west-to-east gradient with lower percentages of resistant bacterial isolates reported in the north and west of Europe have been described.²⁵ This phenomenon is partly linked to the existence and level of implementation of national antimicrobial stewardship strategies.^{7 8} In order to achieve



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the highest possible impact of prudent use guidelines, current prescribing behaviours as well as the regional availability of specific antibiotics need to be taken into consideration. It is therefore crucial to perform studies at a national as well as international level.

In 2015, the Swiss National Strategy on Antibiotic resistance was passed by the federal council. As part of its implementation, an online tool (AntibioticScout.ch) assisting veterinarians in the selection of prudent empirical antimicrobial therapy was created. This tool became available to veterinarians in December 2016.^{26 27}

The aim of this study was to assess antimicrobial use in small animal medicine in Switzerland in 2016, before introduction of the antimicrobial stewardship tool AntibioticScout.ch. Four conditions in dogs for which antimicrobials are frequently prescribed, including acute diarrhoea (AD), urinary tract infections (UTI), respiratory tract infections (RTI) and wound infections (WI), were selected to describe prescription habits of veterinarians and their accordance with national and international prudent use recommendations.^{7-9 28}

MATERIALS AND METHODS

Study design

The study was designed as a retrospective multicentre study involving two university teaching hospitals with annual caseloads of 6000 and 12,000 cases, respectively, and 14 private practices across Switzerland ranging from one-vet mixed practices to middle-sized small animal clinics. It also included one very large private clinic with

over 80,000 cases per year. Antimicrobial prescriptions were assessed for selected diseases in both dogs and cats using the same study design. The results in cats have recently been published.²⁴

Data collection

Electronic medical records were screened via full-text searches for eligible patients using predefined search terms (table 1). Dogs with AD, proven or suspected UTI, proven or suspected RTI and WI were included if they met the inclusion criteria outlined in table 1. Data collection was performed as previously described.²⁴ Briefly, private practices using either OblonData (Amacker & Partner Informatik AG, Switzerland) or Diana SUISSE (Diana Software AG, Switzerland) practice management software were included.

The sample size for private practices was calculated to estimate the prevalence of treatment according to guidelines, corresponding to a justification score of 1 (JS-1) with a precision of ± 8 per cent, assuming a prevalence of 50 per cent, a confidence level of 95 per cent and a population size of 550,000 registered dogs in Switzerland.²⁹ The sample size of 151 cases per indication, which was determined with the Epitools online calculator (<https://epitools.ausvet.io/site/samplesize>), was rounded up to a target sample size of 160. To avoid over-representation of large practices, we limited the number of cases per practice to 16 (10 per cent of the target sample size), which were randomly selected via the sampling function in Excel. For the university clinics, all available cases were

Table 1 Inclusion and exclusion criteria and search terms for the surveyed indications

Indication	Included	Excluded	Search terms
Acute diarrhoea	<ul style="list-style-type: none"> ▶ Diarrhoea <3 weeks. ▶ Acute haemorrhagic diarrhoea syndrome (AHDS). ▶ Parasitic diarrhoea. ▶ Non-specific diarrhoea. 	<ul style="list-style-type: none"> ▶ Diarrhoea >3 weeks or relapsing. ▶ Diarrhoea related to drug administration or another extradigestive disease. ▶ Diarrhoea that appeared during hospitalisation. ▶ Parvovirus. 	Diarrhoea, colitis, duodenitis, enteritis, ileitis, gastritis, AHDS, haemorrhagic gastroenteritis and Giardia, watery stools.
Urinary tract infection	<ul style="list-style-type: none"> ▶ Suspicion or diagnosis of bacterial cystitis. ▶ Suspicion or diagnosis of pyelonephritis. 	<ul style="list-style-type: none"> ▶ Glomerulonephritis. ▶ Leptospirosis. ▶ Urolithiasis without signs of bacteriuria. 	Urinary tract infection, dysuria, difficult urination, stranguria, haematuria, bloody urine, blood in urine, polyuria, pollakiuria, pyelonephritis, inflammation of the bladder, cystitis, bladder and urinalysis.
Respiratory tract infection	<ul style="list-style-type: none"> ▶ Aspiration pneumonia. ▶ Pneumonia (bacterial, viral and unknown). ▶ Bronchitis. ▶ Kennel cough. 	<ul style="list-style-type: none"> ▶ Nasal infections. ▶ Fungal infections. ▶ Neoplasia of the respiratory tract. ▶ Lung worms. 	Respiratory tract infection, respiratory tract disease, cough, tracheitis, tracheobronchitis, pneumonia, inflammation of the lungs, bronchitis, bronchopneumonia, kennel cough, distemper, influenza, adenovirus, dyspnoea and tachypnoea.
Wound infection	<ul style="list-style-type: none"> ▶ Bite wound. ▶ Abscess. 	<ul style="list-style-type: none"> ▶ Anal gland abscess. ▶ Dental abscess. ▶ Abscess due to a foreign body. ▶ Hotspot. 	Wound infection, abscess, purulent wound and bite.

included in order to get close to the target sample size of 160 cases per indication.

Due to the relatively rare occurrence of uncomplicated abscesses and WI at university teaching hospitals, this indication was only assessed in cases from private practices. Signalment, vaccination status, clinical history, clinical examination, treatment with antimicrobials within seven days before presentation, diagnostic work-up, comorbidities as well as hospitalisation length were recorded in addition to parameters relating to antimicrobial therapy including class, dosage, frequency of application and duration of therapy. In dogs with several problems, antimicrobial prescriptions were not recorded, if it was clear that they were given to treat coinfection of a different organ system.

Animals, which were presented again for the same problem, were only included once.

Definitions

Minimal diagnostic work-up was defined as a complete blood count (CBC) for AD, urinary sediment examination for UTI and a CBC and at least one thoracic radiographic view for RTI.

Bacteriuria was defined as the presence of bacteria in sediment analysis or in bacterial culture from an aseptically collected urine sample (cystocentesis). Complicated UTI was defined according to previous guidelines as infection in the presence of anatomical or functional changes or disorders of the immune system, recurrent UTI (three times per year or more) and UTI in non-castrated males.²⁸ These guidelines, which were published in 2011, have since been substantially revised. The revised guidelines have been published in 2019.³⁰

Sepsis criteria were considered fulfilled if dogs showed lethargy in addition to at least one of the following criteria proposed by Hauptman and others³¹: body temperature $>39.4^{\circ}\text{C}$, heart rate $>140/\text{min}$, white blood cell (WBC) <4 or $>25 \times 10^9/\text{l}$ and banded neutrophils $>1.5 \times 10^9/\text{l}$.

Cases of RTI were categorised as severe if the dogs fulfilled above-mentioned sepsis criteria in addition to signs of pulmonary involvement, either by auscultation (crackles) or on at least one lateral thoracic radiograph. A more detailed severity score could not be applied because relevant data were commonly missing from the medical records. For the same reason, the severity of disease was not assessed in the remaining three indications.

In accordance with WHO guidelines,³² highest priority critically important antimicrobials (HPClAs) were defined as third-generation or fourth-generation cephalosporins, quinolones, macrolides, ketolides, glycopeptides and polymyxins. Combination therapy was defined as the prescription of two or more antibiotic classes at the same time.

Justification score

Antimicrobial prescriptions were compared with the recommendations summarised in table 2, which were based on existing consensus national and international

guidelines.^{7-9 28} A previously published justification score (JS-1 to JS-4)³³ was used with modifications to evaluate the appropriateness of the prescription in all cases where sufficient clinical information was available (table 3).

For the duration and dosage, ± 1 day and up to ± 20 per cent deviations were accepted.

Statistical analysis

Data were evaluated using a commercial statistical software package (NCSS11 Statistical Software (2016) ncss.com/software/ncss). Descriptive statistics were used for patient characteristics including sex, age and prescribed antimicrobials (table 4). Shapiro-Wilk testing revealed non-normal distribution for age, weight and duration of treatment (in each category), which were therefore reported as median and IQR. Patient characteristics, antimicrobial pretreatments, differences in diagnostic work-up, antibiotic classes, the use of HPClAs and duration of therapy were recorded and compared between dogs presented to university hospitals and private practices using the chi-squared test or Fisher's exact test when the expected value in a cell was <5 for categorical and the Mann-Whitney test for continuous variables. The Bonferroni method was applied to correct the significance levels for multiple comparisons.

Risk factors for the unfavourable JS-3 and JS-4 and for the prescription of HPClAs were identified using univariate logistic regression analysis. The following potential risk factors were assessed: presence of haemorrhagic diarrhoea, presence of leucopenia or leukocytosis and the presence of a left-shift for AD; complicated UTI, non-castrated male status and urinary catheterisation for UTI; and duration of clinical signs ≤ 7 days, lacking or not up to date vaccinations, lack of minimal work-up, hospitalisation and presence of a left shift for RTI. Finally, for WI, age less than three years, hospitalisation, local treatment of the wound and presence of a left shift were examined. All other associations were studied using the chi-squared test. Multivariable logistic regression analysis was attempted, but due to the low number of dogs in each category for which detailed clinical information was available, no relevant associations could be identified. Results are reported as per cent with 95 per cent CIs where appropriate or as ORs with 95 per cent CIs. Significance was set at $P < 0.05$ for all tests apart from the post hoc multiple comparisons.

RESULTS

Case characteristics

A total of 1065 dogs were included in the study, 343 of which were presented at university hospitals and 722 at private practices. Case characteristics are shown in table 4. Age and sex were not significantly different between the dogs seen at university hospitals and those seen at private practices. Dogs presented to a university hospital were significantly more likely to be pretreated with antimicrobials (24 per cent, 95 per cent CI 0.19 per

Table 2 Criteria used to judge appropriate use of antimicrobials based on national and international recommendations^{7-9 28}

Indication	Comment	Antimicrobial	Dosage (mg/kg)	Application frequency	Treatment duration (days)
Acute diarrhoea	Antimicrobial therapy NOT indicated unless clinical suspicion of sepsis based on clinical and laboratory data.* ^{7–9}	Ampicillin	20	Twice daily/three times a day	5–7
		Amoxicillin	11–15	Twice daily/three times a day	5–7
		Amoxicillin/clavulanic acid	12.5–20	Twice daily/three times a day	5–7
		Ampicillin/sulbactam‡	30	Twice daily/three times a day	5–7
	If suspicion of sepsis* and no improvement with initial therapy after two to three days, antimicrobial spectrum may be extended by adding. ^{7–9}	Enrofloxacin OR	10–20	Once daily	5–7
		Marbofloxacin AND/OR	2	Once daily	5–7
		Metronidazole	15	Twice daily	5–7
UTIs	According to 2011 guidelines, complicated UTIs are defined as infections caused by anatomical or functional changes or disorders of the immune system, recurrent UTI /three times per year or more) or UTI in non-castrated male. ²⁸	Sporadic (uncomplicated) UTI			
		Amoxicillin	11–15	Twice daily/three times a day	5–7
		Ampicillin†	20	Twice daily/three times a day	5–7
		Complicated UTI			
		Amoxicillin	11–15	Twice daily/three times a day	5–28
		Amoxicillin/clavulanic acid	12.5–20	Twice daily/three times a day	5–28
		Ampicillin†	2020	Twice daily/three times a day	5–28
		Ampicillin/sulbactam‡	30	Twice daily/	5–28
		Trimethoprim/sulfadiazin	15	Twice daily	5–28
		Trimethoprim/sulfamethoxazole	15	Twice daily	5–28
		Non-castrated male dogs			Once daily
		Enrofloxacin	10–20	Once daily	5–42
		Marbofloxacin	2	Twice daily	5–42
		Trimethoprim/sulfadiazin	15	Twice daily	5–28
		Trimethoprim/sulfamethoxazole	15		5–28
Respiratory tract infections	Aspiration pneumonia or bacterial bronchopneumonia. ^{7–9}	Mild to moderate disease			Treatment 1 week beyond resolution of clinical/ radiographic signs
		Doxycycline	10	Once daily	
		Amoxicillin/clavulanic acid	12.5–20	Twice daily/three times a day	
		Ampicillin/sulbactam‡	30	Twice daily/three times a day	
		Severe cases			
		Amoxicillin/clavulanic acid OR	12.5–20	Twice daily/three times a day	
		Ampicillin/sulbactam‡	30	Twice daily/three times a day	
		AND			
	Enrofloxacin OR	10–20	Once daily		
	Marbofloxacin	2	Once daily		
	Kennel cough: antimicrobial therapy only indicated if: poor general condition, rectal T>39.4°C or signs of lower airway involvement. ^{7–9}	Doxycycline	10	Once daily	5–14

Continued

Table 2 Continued

Indication	Comment	Antimicrobial	Dosage (mg/kg)	Application frequency	Treatment duration (days)
Wound infections	Bite wounds: antimicrobial therapy always indicated, except damage limited to epidermis. Abscesses: antimicrobial therapy only indicated if fever, reduced general demeanour, very contaminated wound or proximity to fragile tissues (ie, joints). ⁷⁻⁹	Amoxicillin/clavulanic acid	12.5–20	Twice daily	Abscesses or superficial¶ bite wounds: 5–7.
		Cefalexin	20–35	Twice daily/three times a day	Deep** or penetrating bite wounds: 7–10.
		Clindamycin	10–15	Twice daily	

*Sepsis criteria used: lethargy plus at least one of the following: body temperature >39.4°C, heart rate >140/min, WBC <4 or >25×10⁹/l and banded neutrophils >1.5×10⁹/l.

†Intravenous or subcutaneous.

‡Intravenous.

§Severe clinical, laboratory or radiographic signs.

¶Only skin damaged.

**Skin and deeper structures damaged.

UTI, urinary tract infection.

cent to 0.28 per cent vs 2 per cent, 95 per cent CI 0.01 per cent to 0.04 per cent; $P<0.001$) and were significantly more frequently hospitalised (250/343; 73 per cent, 95 per cent CI 0.68 per cent to 0.78 per cent) compared with private practice (29/722; 4 per cent, 95 per cent CI 0.03 per cent to 0.06 per cent; $P<0.001$).

Antimicrobial prescription overall

In total, 786 (74 per cent) dogs received antimicrobials either as monotherapy (94 per cent) or combination therapy (6 per cent). The most used antimicrobials were potentiated aminopenicillins (59 per cent), followed by nitroimidazoles (22 per cent), non-potentiated aminopenicillins (16 per cent), fluoroquinolones (13 per cent), tetracyclines (5 per cent), first-generation (4 per cent) and third-generation cephalosporins (2 per cent). The proportion of dogs receiving combination therapy was significantly higher at university hospitals (34/343; 13 per cent, 95 per cent CI 0.07 per cent to 0.14) compared with private practices (13/520; 3 per cent, 95 per cent CI 0.01 per cent to 0.04 per cent; $P<0.001$).

There was no difference in the frequency of prescription of HPCIAs between university hospitals and private

practices. Non-potentiated aminopenicillins were prescribed significantly more commonly in private practices (16 per cent, 95 per cent CI 0.14 per cent to 0.19 per cent) compared with university hospitals (3 per cent, 95 per cent CI 0.01 per cent to 0.04 per cent; $P<0.001$).

At university hospitals, a significantly higher proportion of prescriptions were in complete accordance (JS-1 48 per cent, 95 per cent CI 0.42 per cent to 0.53 per cent vs 34 per cent, 95 per cent CI 0.30 per cent to 0.37 per cent; $P<0.001$) or complete discordance (JS-4 35 per cent, 95 per cent CI 0.30 per cent to 0.40 per cent vs 28 per cent, 95 per cent CI 0.25 per cent to 0.31 per cent; $P=0.02$) with consensus guidelines compared with private practices. A significantly higher proportion of dogs at university hospitals was treated with an antimicrobial class not recommended in guidelines compared with private practice (JS-3 13 per cent, 95 per cent CI 0.09 per cent to 0.17 per cent vs 5 per cent, 95 per cent CI 0.04 per cent to 0.07 per cent; $P<0.001$). The proportions of dogs receiving an incorrect dosage or treatment duration (JS-2) was not significantly different between university hospitals and private practices (3 per cent, 95 per cent CI 0.01 per cent to 0.05 per cent vs 4 per cent, 95 CI per cent 0.03 per cent to 0.06 per cent; $P=0.3$).

No differences were found between the two university hospitals regarding the prescription of HPCIA (s) ($P=0.3$), of fluoroquinolones ($P=0.2$) or the use of combination therapy ($P=0.5$). Moreover, there was no significant difference in the number of cases in agreement ($P=0.5$) or disagreement ($P=0.6$) with the guidelines. The only significant difference between the two university hospitals was in the number of hospitalised patients (86 per cent, 95 per cent CI 0.79 per cent to 0.92 per cent vs 65 per cent, 95 per cent CI 0.58 per cent to 0.71 per cent; $P<0.001$).

Antimicrobial prescriptions for AD

Numbers and proportions of diagnostic procedures, antimicrobial prescriptions and justification scores for dogs with AD are shown in table 5.

Table 3 Modified justification score used to judge the accordance of antimicrobial prescriptions in dogs³³

Justification score	Criteria
JS-1	Empirical treatment in accordance with national and international recommendations, that is, correct indication, antimicrobial class, dosage and treatment duration OR correct treatment according to culture and sensitivity profile OR no antibiotic needed and none prescribed.
JS-2	Wrong dosage and/or duration of treatment.
JS-3	Wrong antimicrobial class.
JS-4	Decision to treat NOT in accordance with guidelines, that is, antibiotic prescription when not indicated or no antibiotic prescription although indicated.

Table 4 Characteristics of 1065 dogs presented for acute diarrhoea, suspected or confirmed urinary tract infections, respiratory tract infections or wound infections to university hospitals or private practices

Parameter	Acute diarrhoea			Urinary tract infections			Respiratory tract infections			Wound infections	
	University hospitals	Private practices	P value*	University hospitals	Private practices	P value*	University hospitals	Private practices	P value*	Private practices	
Total	165	206		70	175		108	166		175	
Sex			0.4			0.2			0.3		
Female, n (%)	74 (45)	99 (48)		39 (56)	112 (64)		56 (52)	73 (44)		91 (52)	
Male, n (%)	91 (55)	102 (50)		31 (44)	61 (35)		52 (48)	91 (55)		81 (46)	
Unknown, n (%)	0	5 (2)		0	2 (1)		0	2 (1)		3 (2)	
Age (years), median (IQR)	5 (2–8)	6 (1–9)	0.5	10 (6–12)	8 (3.3–10.8)	0.02	6 (2–11)	7 (2–11)	0.9	6 (3–9.5)	
Weight (kg), median (IQR)	10 (8–13)	13 (10–17)	0.03	18 (13–23)	21 (16–25)	<0.001	14 (9–19)	11 (9–17)	0.8	21 (11–28)	
Breed			0.2			0.6			0.07		
Purebred, n (%)	140 (85)	165 (80)		58 (83)	136 (76)		93 (86)	133 (80)		133 (76)	
Mixed breed, n (%)	22 (13)	38 (18)		12 (17)	35 (20)		11 (10)	31 (19)		40 (23)	
Unknown, n (%)	3 (2)	3 (2)		0	4 (3)		4 (4)	2 (1)		2 (1)	

*Statistically significant P values after Bonferroni correction ($P < 0.02$) are written in bold characters.

Table 5 Diagnostic work-up and antibiotic prescriptions in 371 cases of canine acute diarrhoea cases presented to university hospitals or private practices

Parameter	University hospitals	Private practices	P value*
Total number of cases	165	206	
Minimal diagnostic work-up, n (%)†			
Yes	131 (79)	12 (6)	<0.001
No	34 (20)	194 (94)	
Sepsis criteria fulfilled, n (%)‡			
Yes	34 (21)	21 (10)	0.08
No	129 (78)	134 (65)	
Unknown	2 (1)	51 (25)	
Haemorrhagic diarrhoea, n (%)			
Yes	101 (61)	52 (25)	<0.001
No	64 (39)	132 (64)	
Unknown	0 (0)	22 (11)	
Hospitalisation, n (%)			
Yes	141 (85)	9 (4)	<0.001
No	24 (15)	197 (96)	
Pretreated, n (%)			
Yes	24 (15)	0 (0)	<0.001
No	138 (84)	194 (94)	
Unknown	3 (1)	12 (6)	
Antibiotic therapy, n (%)			
Yes	116 (70)	127 (62)	0.08
Antibiotic classes, n (%)			
Potentiased aminopenicillins	55 (47)	13 (10)	<0.001
Nitroimidazole	74 (64)	100 (79)	0.5
Non-potentiased aminopenicillins	0 (0)	9 (6)	0.007
Third-generation cephalosporins	0 (0)	3 (2)	0.1
Tetracyclines	0 (0)	3 (2)	0.1
Fluoroquinolones	3 (3)	15 (12)	0.01
Combination therapy, n (%)			
Yes	11 (9)	6 (5)	0.1
No	105 (91)	121 (95)	
HPCIA, n (%)§			
Yes	3 (3)	18 (14)	0.004
No	113 (97)	109 (86)	
Duration of therapy (days)			
Median (IQR)	8 (7–9)	6 (5–7)	<0.001
Justification score, n (%)			
1	57 (35)	62 (30)	0.4
2	5 (3)	0 (0)	0.01

Continued

Table 5 Continued

Parameter	University hospitals	Private practices	P value*
3	15 (9)	3 (1)	<0.001
4	88 (53)	102 (50)	0.5
Judgement not possible	1 (0.6)	39 (19)	

*Statistically significant P values after Bonferroni correction are written in bold characters.

†Minimal work-up is CBC.

‡Criteria fulfilled if lethargic and at least one of the following: body temperature >39.4°C, heart rate >140/min, WBC <4 or >25×10⁹/l and band neutrophils >1.5×10⁹/l.

§HPCIA: highest priority critically important antimicrobials include third-generation or higher generation cephalosporins, quinolones, macrolides, ketolides, glycopeptides and polymyxins. CBC, complete blood count; WBC, white blood cell.

Of the 371 dogs presented for AD, 243 (65 per cent) received antimicrobial therapy with the following classes: nitroimidazoles (72 per cent), potentiased aminopenicillins (28 per cent), fluoroquinolones (7 per cent), non-potentiased aminopenicillins (4 per cent), third-generation cephalosporins (1 per cent) and tetracyclines (1 per cent). Combination therapy was prescribed in 7 per cent of the cases and was associated with the presence of sepsis criteria.³¹ Twenty-one dogs (8 per cent) received a least one HPCIA. The use of HPCIA was not associated with the presence of sepsis criteria. The duration of the treatment was significantly longer at university hospitals compared with private practices.

A total of 143 dogs (39 per cent) underwent minimal diagnostic work-up (CBC) and 84 dogs (23 per cent) had a coprological examination performed. *Giardia* species was detected in 10/84 dogs and 7 of them received metronidazole.

Dogs presenting at university hospitals had significantly more haemorrhagic diarrhoea than those presenting at private practices (P<0.001). The presence of haemorrhagic diarrhoea was significantly associated with the use of antibiotics (P<0.001) and hospitalisation (P<0.001) but not with the presence of sepsis criteria (P=0.08). Univariate logistic regression analysis also showed that the odds for an incorrect utilisation of antimicrobials (JS-4) was 2.26 times higher in dogs with haemorrhagic diarrhoea (95 per cent CI 1.46 to 3.51; P<0.001).

Subgroup analysis of 55 dogs for which criteria of sepsis were fulfilled showed no significant difference regarding the overall antimicrobial prescription rate (P=0.1) nor the prescription of HPCIA (P=0.05) between university hospitals and private practices. However, there were significantly more cases in total disagreement with the guidelines at private practices (62 per cent) than at university hospitals (9 per cent; P<0.001).

When looking at the subgroup of 153 dogs with haemorrhagic diarrhoea, there was no significant difference between university hospitals and private practices with regards to the overall antimicrobial prescription rate

($P=0.6$) and the prescription of HPClAs ($P=0.08$) as well the number of prescriptions in complete agreement ($P=0.9$) or complete disagreement ($P=0.3$) with consensus guidelines.

When looking at the subgroup of 160 dogs with AD that were hospitalised, there was no statistical difference between university hospitals and private practices regarding the overall antimicrobial prescription rate. However, HPClAs were more frequently used at private practices (16 per cent) than at university hospitals (2 per cent, $P=0.003$). A significantly higher proportion of cases was judged in total agreement (33 per cent vs 5 per cent; $P=0.01$) and a significantly lower proportion in complete disagreement (53 per cent vs 84 per cent; $P=0.01$) with guidelines at university hospitals than at private practices.

Agreement with consensus guidelines could be evaluated in 89 per cent (331/371) of dogs with AD. In these dogs, treatment was in total compliance with the consensus guidelines (JS-1) in 36 per cent of the cases and in total disagreement in 57 per cent of dogs (JS-4). For 18 (5 per cent) cases, the chosen antimicrobial class was not in agreement with the consensus guidelines (JS-3). In the majority of these cases (17/18), metronidazole was used instead of or in combination with the recommended potentiated aminopenicillins. The dogs with a JS-4 score were either treated when not needed (187/190; 98 per cent) or not treated when needed (3/190; 2 per cent).

Antimicrobial prescription for UTI

Numbers and proportions of diagnostic procedures, antimicrobial prescriptions and justification scores for UTI are shown in table 6. Antimicrobials were prescribed in 215/245 dogs (88 per cent) with suspected or proven UTI. The following antimicrobials were prescribed as either monotherapy (98 per cent) or combination therapy (2 per cent): potentiated aminopenicillins (61 per cent), fluoroquinolones (22 per cent), non-potentiated aminopenicillins (11 per cent), first-generation cephalosporins (5 per cent), third-generation cephalosporins (1 per cent), lincosamides (0.8 per cent), amphenicols (0.4 per cent) and potentiated sulfonamides (0.4 per cent). All five dogs receiving combination therapy had urinary culture and antimicrobial susceptibility testing performed, demonstrating infection with MDROs in three and the presence of two different bacteria with different resistance profiles in two dogs.

The most frequently employed HPClAs were fluoroquinolones, and their use was not associated with a non-castrated male status ($P=0.3$). There was a borderline association between the presence of MDROs in urine and the use of HPClAs ($P=0.06$).

Diagnostic work-up (microscopic sediment analysis or culture) was significantly more commonly performed at university hospitals compared with private practices. Of all dogs receiving antimicrobials, 85 (40 per cent) had a confirmed bacterial aetiology.

In 50 per cent of the total cases, a justification score could not be attributed because of a lack of data and/or

Table 6 Diagnostic work-up and antibiotic prescriptions in 245 dogs with suspected UTIs presented to university hospitals or private practices

Parameter	University hospital	Private practice	P value*
Number of cases	70	175	
Microscopic sediment analysis, n (%)			
Yes	59 (84)	73 (42)	<0.001
No	11 (16)	81 (46)	
Bacterial culture, n (%)			
Yes	67 (96)	43 (25)	<0.001
No	3 (4)	132 (75)	
UTI considered complicated, n (%)*†			
Yes	48 (69)	46 (26)	<0.001
Bacteriuria, n (%)‡‡			
Confirmed	62 (88)	27 (15)	<0.001
Excluded	7 (10)	22 (13)	
No enough data to confirm or exclude bacterial aetiology	1 (2)	126 (72)	
Hospitalisation, n (%)			
Yes	40 (56)	5 (3)	<0.001
No	30 (44)	170 (97)	
Pretreated, n (%)			
Yes	14 (20)	6 (3)	<0.001
No	54 (77)	162 (93)	
Unknown	2 (3)	7 (4)	
Antibiotic therapy			
Yes	68 (97)	147 (84)	0.3
No	2 (3)	28 (16)	
Antibiotic classes, n (%)			
Potentiated aminopenicillins	53 (78)	97 (65)	0.07
Fluoroquinolones	12 (17)	43 (29)	
Non-potentiated aminopenicillins	5 (7)	22 (15)	0.2
First-generation cephalosporins	2 (3)	11 (7)	
Third-generation cephalosporins	0 (0)	3 (2)	0.2
Lincosamide	2 (3)	0 (0)	
Amphenicols	1 (1)	0 (0)	0.1
Potentiated sulfonamides	1 (1)	0 (0)	
Combination therapy, n (%)			
Yes	5 (7)	0 (0)	<0.001
No	63 (93)	147 (100)	
HPCIA‡§			
Yes	11 (16)	47 (32)	0.03
No	57 (84)	100 (68)	
Duration of therapy (days)			
Median (IQR)	18 (10–27)	11 (7–14)	<0.001

Continued

Table 6 Continued

Parameter	University hospital	Private practice	P value*
Justification score, n (%)			
1	38 (54)	11 (6)	<0.001
2	4 (6)	1 (0.5)	0.01
3	13 (19)	17 (10)	0.06
4	14 (20)	25 (14)	0.3
Judgement not possible	1 (1)	121 (69)	

*Statistically significant P values after Bonferroni correction are written in bold characters

†Complicated UTI defined according to previous guidelines as infections in the presence of anatomical or functional changes or disorders of the immune system, recurrent UTI (three times per year or more) and UTI in non-castrated males.²⁸

‡Defined as either positive microscopic sediment analysis or positive bacterial culture.

§HPCIA: highest priority critically important antimicrobials include third-generation or higher generation cephalosporins, quinolones, macrolides, ketolides, glycopeptides and polymyxins.

UTI, urinary tract infection.

diagnostic work-up. Of all dogs for which a justification score could be given, complete accordance to the guidelines (JS-1) was observed in 49 dogs (20 per cent) and significantly more often at university hospitals compared with private practices (54 per cent vs 6 per cent; $P<0.001$). In 24 per cent of the dogs an inappropriate antimicrobial was prescribed (JS-3). In most of the cases, potentiated aminopenicillins were chosen as first-line treatment instead of non-potentiated aminopenicillins. The dogs with a JS-4 score were either treated when not needed (37/39; 95 per cent) or not treated when needed (2/39; 5 per cent).

Antimicrobial prescription for RTI

Numbers and proportions of diagnostic procedures, antimicrobial prescriptions and justification scores for RTI are shown in table 7. Of the 274 dogs, which were treated for suspected or confirmed RTI, 171 (62 per cent) received monotherapy or combination antimicrobial therapy of the following classes: potentiated aminopenicillins (43 per cent), tetracyclines (14 per cent), non-potentiated aminopenicillins (12 per cent), fluoroquinolones (10 per cent), first-generation (1 per cent) and third-generation cephalosporins (1 per cent). The use of HPCIA and the prescription of combination therapies were significantly more frequent at university hospitals ($P<0.001$). The use of combination therapy was not associated with cases categorised as severe ($P=0.07$). Minimal work-up (CBC and thoracic radiographs) was more commonly performed at university hospitals (69 per cent vs 0.9 per cent; $P<0.001$). A diagnosis of aspiration pneumonia was made in 42 dogs (15 per cent) and 28 (10 per cent) dogs were diagnosed with kennel cough. In 13 dogs (5 per cent), a diagnosis of bronchitis resulted from radiography and also sometimes endoscopy, 3 dogs

Table 7 Diagnostic work-up and antibiotic prescriptions in 274 dogs with respiratory tract infections presented to university hospitals or private practices

Parameter	University hospital	Private practice	P value*
Number of cases	108	166	
Duration of clinical signs, n (%)			
<7 days	49 (45)	49 (30)	0.03
>7 days	34 (31)	15 (9)	
Unknown	25 (23)	102 (61)	
Minimal work-up, n (%)†			
Yes	75 (69)	1 (0.6)	<0.001
Broncho-alveolar lavage and culture, n (%)			
Yes	8 (7)	2 (1)	0.007
Cases judged severe, n (%)‡			
Yes	25 (24)	1 (0.6)	0.7
No	3 (3)	0 (0)	
Impossible to judge	80 (73)	165 (99.4)	
Diagnosis based on clinical signs in addition to, n (%)			
Clinical examination alone	15 (14)	145 (87)	<0.001
Clinical examination and radiographs	72 (66)	16 (10)	<0.001
Clinical examination, radiographs (optional) and bronchoscopy	12 (11)	6 (4)	0.014
Clinical examination, radiographs (optional), bronchoscopy and BAL	8 (7)	2 (1)	0.007
Hospitalisation, n (%)			
Yes	69 (54)	1 (0.6)	<0.001
No	39 (36)	165 (99.4)	
Pretreated, n (%)			
Yes	41 (37)	7 (4)	<0.001
No	66 (62)	158 (95.4)	
Unknown	1 (1)	1 (0.6)	
Antibiotic therapy, n (%)			
Yes	82 (76)	89 (49)	<0.001
No	26 (24)	77 (51)	
Antibiotic classes, n (%)			
Potentiated aminopenicillins	59 (71)	58 (65)	0.3
Tetracyclines	12 (15)	26 (29)	0.03
Non-potentiated aminopenicillins	2 (2)	33 (37)	<0.001
Fluoroquinolones	23 (28)	4 (4)	<0.001
First-generation cephalosporins	4 (5)	0 (0)	<0.001
Third-generation cephalosporins	1 (1)	3 (3)	0.4
Combination therapy, n (%)			
Yes	18 (22)	4 (5)	<0.001
No	64 (88)	85 (95)	

Continued

Table 7 Continued

Parameter	University hospital	Private practice	P value*
HPCIA§			
Yes	25 (30)	7 (8)	<0.001
No	57 (70)	82 (92)	
Duration of therapy (days)			
Median (IQR)	12.7 (3–20)	6.3 (0–10)	<0.001
Justification score, n (%)			
1	68 (63)	64 (39)	<0.001
2	1 (1)	3 (2)	0.6
3	15 (14)	11 (7)	0.04
4	19 (18)	45 (27)	0.06
Judgement not possible	5 (5)	43 (26)	<0.001

*Statistically significant P values after Bonferroni correction are written in bold characters.

†Minimal work-up consist of a thoracic radiograph and CBC.

‡Cases were judged as severe if there was a reduced general state+signs of SIRS (systemic inflammatory response syndrome)/sepsis/left-shift+pulmonary involvement (radiographs or auscultation).

§HPCIA: highest priority critically important antimicrobials include third-generation or higher generation cephalosporins, quinolones, macrolides, ketolides, glycopeptides and polymyxins.

BAL, broncho-alveolar lavage; CBC, complete blood count.

(0.1 per cent) were diagnosed with pneumonia based on consistent radiographic changes, 3 dogs (0.1 per cent) with eosinophilic bronchopathy and 1 dog (0.03 per cent) with distemper. The remaining cases (183 dogs, 67 per cent) were classified as ‘unknown’ in the absence of a definitive diagnosis. Those cases were more frequently seen at private practices (150/183; $P<0.001$).

Agreement with consensus guidelines could be evaluated in 82 per cent (226/274) of dogs with RTI. Of all dogs for which a justification score could be given, 132 cases (58 per cent) were managed according to the guidelines (JS-1). There were significantly more cases with a justification score JS-1 among the university hospitals than private practices (63 per cent vs 39 per cent; $P<0.001$). A total of 93 (42 per cent) cases were not treated in agreement with the guidelines for prudent antimicrobial prescription (JS-2: 3, 1 per cent; JS-3: 26, 13 per cent; JS-4: 64, 28 per cent). The dogs with a JS-4 score were either treated when not needed (62/64; 97 per cent) or not treated when needed (2/64; 3 per cent).

Antibiotic prescription for abscesses and bite wounds (WI)

Numbers and proportions of diagnostic procedures, antimicrobial prescriptions and justification scores are shown in table 8. Of the 175 dogs treated for abscesses or bite wounds at private practices, 157 (90 per cent) received monotherapy or combination antimicrobial therapy.

Forty per cent of dogs presented for abscess (16/40) had at least one clinical sign listed in the guidelines (fever, lethargy, severely contaminated wound or proximity to fragile tissues) justifying systemic antimicrobial treatment. Thirty per cent of those presented for bite

Table 8 Presence of clinical signs and antibiotic prescription in 175 dogs with wound infections presented to private practices

Parameter	Private practice, n (%)
Number of cases	175
Type of lesion	
Abscess	40 (23)
Bite	135 (77)
Local wound treatment	
Yes	113 (65)
No	14 (8)
Unknown	48 (27)
Drain placed	
Yes	14 (8)
No	161 (92)
Antibiotic therapy	
Yes	157 (90)
No	18 (10)
Antibiotic classes	
Potentiased aminopenicillins	132 (75)
Non-potentiased aminopenicillins	54 (31)
First-generation cephalosporins	18 (10)
Fluoroquinolones	5 (3)
Third-generation cephalosporins	2 (1)
Lincosamide	1 (0.5)
Penicillins	0 (0)
Combination therapy	
Yes	3 (2)
HPCIA*	
Yes	7 (4)
Duration of therapy: days (IQR)	7.6 (5.9–10)
Justification score	
1	105 (60)
2	26 (15)
3	6 (3)
4	28 (16)
Judgement not possible	10 (6)

*HPCIA: highest priority critically important antimicrobials include third-generation or higher generation cephalosporins, quinolones, macrolides, ketolides, glycopeptides and polymyxins.

wounds had at least one clinical sign listed in the guidelines (bite wound penetrating the epidermis), justifying antimicrobial use. Data were not enough for a judgement in 10 cases (6 per cent). A total of 105 cases (64 per cent) were treated in complete accordance with guidelines (JS-1), whereas 60 (36 per cent) were not (JS-2: 26, 16 per cent; JS-3: 6, 4 per cent; JS-4: 28, 17 per cent). The dogs

with a JS-4 score were either treated when not needed (15/28; 54 per cent) or not treated when needed (13/28; 46 per cent). Dogs not treated when needed were in the vast majority (12/13) dogs with bite wounds.

DISCUSSION

The results of this study demonstrate that there is ample room for improvement regarding the prudent use of antimicrobials in Switzerland, as inappropriate prescriptions were common for dogs with AD, UTI, RTI and WI. Indeed, in 41 per cent of cases, antimicrobial treatment was in partial or complete disagreement with national and international guidelines. These findings concur with studies in human and veterinary medicine showing that antimicrobials are commonly prescribed without clear indication,^{10 11 13 16 18 19 21 34 35} that HPClAs are used as first-line agents^{12 15 23} and that adherence to general guidelines is often poor, both in hospital^{10 21 36 37} and first opinion practice settings.^{12 16 38} The results also concur with the situation in selected feline conditions in Switzerland where 38 per cent of antimicrobial treatments were found to be in partial or total disagreement with consensus guidelines. In that study HPClAs, in particular third-generation cephalosporins, were used as first-line treatment in up to 20 per cent of cases.²⁴ Possible reasons for the high rate of inappropriate antimicrobial prescriptions in Switzerland in 2016 likely include the absence of national guidelines before the introduction of AntibioticScout.ch and a lack of emphasis on prudent antimicrobial use in the veterinary curriculum.

The challenges and reasons for poor adherence to prudent use recommendations likely vary considerably between referral and first opinion practices as patient populations and owner expectations may be very different.^{36 39–41} In this cohort of dogs, pretreatment with antimicrobials was significantly more common in dogs presented to university hospitals, where the diagnostic work-ups were generally more complete, a higher proportion of patients were hospitalised, had more severe disease and received a combination of antimicrobials. All these factors are consistent with a referral population, which may be characterised by more complex illness and owners more willing to pursue further diagnostics. However, owner expectations for antimicrobial treatment after minimal diagnostic work-up has been reported as one of the barriers to prudent antimicrobial use in first opinion practice.^{39–42} Moreover, expertise of the staff, access to diagnostic tools and the existence and level of implementation of local policies for the use of antimicrobials may also vary between university hospitals and private practices.

Regarding the overall choice of antimicrobials across all four selected disease groups, aminopenicillins were the most commonly prescribed antimicrobials, which is also reflected by the national sales figures⁴³ and concurs with reports from other countries.^{12 16 18 44} Third-generation cephalosporins were rarely used in this cohort of dogs,

which is in contrast to data from cats in Switzerland and elsewhere.^{23 24 45 46} Cefovecin is the only long-acting injectable third-generation cephalosporin registered for use in dogs and cats in Switzerland at present. Cefovecin is licenced to treat infections of skin, soft tissues, gingiva and urinary tract in dogs and cats. The rare use of third-generation cephalosporins in this cohort is likely due to the choice of indication (ie, skin infections were not included) and the fact that it is easier to administer oral drugs in dogs than in cats.

When looking at the overall antimicrobial prescriptions, no difference was found between the two university hospitals. This could be because similar local antimicrobial policies are used. In addition to that, further consensus was built while collaborating on the development of the guidelines used for the Antibioticscout.ch online tool²⁶ and the preparation of this present study during the year of 2017.

In this study, two-thirds of dogs with AD received antimicrobials even though dogs with parvovirus were excluded from the analysis. Current guidelines only recommend the use of antimicrobials in dogs with AD if clinical or laboratory signs consistent with sepsis are present,^{7–9} but in this cohort, the use of antimicrobials was not significantly associated with the presence of sepsis. Instead the use of antimicrobials was clearly associated with the presence of haemorrhagic diarrhoea. These results concur with the results of a national retrospective study in the UK showing that over 80 per cent of dogs with haemorrhagic diarrhoea received antimicrobials and often a combination of two antimicrobials.⁴⁶ This reflects the previous belief that haemorrhagic diarrhoea is associated with a higher risk of bacterial translocation and therefore requires antimicrobial treatment.⁴⁷ Recent evidence however does not support this concept, as dogs with acute haemorrhagic diarrhoea syndrome (AHDS) were no more likely to have positive blood cultures than healthy controls.⁴⁸ Furthermore, in a prospective placebo controlled clinical trial in a population of 60 dogs with AHDS, there were no significant differences between the group of dogs receiving intravenous amoxicillin-clavulanic acid and controls regarding the number of hospitalisation days, clinical score and outcome.⁴⁹ The use of antimicrobials should therefore be reserved for AD patients with clinical signs of sepsis.

Metronidazole was the most commonly used antimicrobial in dogs with AD. Metronidazole and fenbendazole have been used interchangeably in the past to treat clinical giardiasis and might have been the reason for prescription of metronidazole in some of the dogs even though fenbendazole is now the recommended first-line treatment.⁴⁷ Metronidazole is commonly used by small animals practitioners, as it is believed to reduce the duration of clinical signs and the severity of diarrhoea, although evidence is lacking. While nitroimidazoles are not classified as critically important antimicrobials in Switzerland, their use to treat AD should nevertheless be restricted. Metronidazole is used in human medicine

for the treatment of often life-threatening *Clostridium* infections, and the number of metronidazole-resistant bacterial isolates from animals and humans is rising.⁵⁰ Metronidazole may increase the risk of selection of multidrug resistant *E coli*^{50 51} and possibly favours bacterial translocation.⁵² Finally, metronidazole can cause a potentially severe neurotoxicity in dogs,^{53–55} as well in humans^{56–59} and should therefore be used cautiously.

Minimal diagnostic work-up was limited to CBC in the group of AD, as the presence of neutropenia, neutrophilia and/or a left-shift are important sepsis criteria.³¹ Parasitological examination of faeces was not included in the minimal diagnostic work-up, as it was commonly replaced by the use of broad-spectrum antiparasitic treatments. Faecal culture and PCR for specific pathogens such as *Campylobacter* spp or *Clostridia* spp were also not considered core elements of the work-up, because there is not a clear link between the presence of these pathogens in the gut and the occurrence of diarrhoea in dogs.^{60–62}

In the group of dogs with UTI, 88 per cent of dogs received antimicrobial treatments, even though a bacterial aetiology was confirmed in only 36 per cent of cases, either via sediment analysis or culture. This is consistent with results of other national studies.^{15 63} It is very common for patients of first opinion practices with acute signs of lower urinary tract disease to receive empirical antimicrobial treatment without prior urinalysis and/or culture. In a previous questionnaire-based study, only 32.5 per cent of companion animal practitioners in Europe reported that they frequently undertake antimicrobial susceptibility testing when prescribing antimicrobials, whereas 9.1 per cent never requested such tests.⁴¹ Similarly, in a US study, only 38 per cent of dogs with suspicion of UTI receiving antimicrobials had a definitive diagnosis of bacterial infection.¹⁰ While in dogs with lower urinary tract signs, bacterial UTIs are more common than in cats, the presence of bacteria should nevertheless be confirmed via sediment analysis and/or culture before starting antimicrobial therapy.^{28 30} This is emphasised by the fact that around 50 per cent of urine samples of dogs with clinical signs of UTI are sterile on culture.^{63 64}

Similar to previous studies,^{10 17 63} potentiated aminopenicillins were used more commonly than non-potentiated aminopenicillins to treat sporadic UTI in this cohort, although non-potentiated aminopenicillins are the recommended choice.^{26 30} The use of non-potentiated aminopenicillins is preferred whenever possible, because the addition of clavulanic acid increases AmpC-mediated resistance to first-generation, second-generation and third-generation cephalosporins.^{65 66} Fluoroquinolones were the second most commonly used antimicrobials, and their use was associated with, but not restricted to, non-castrated males. The use of antimicrobials with good penetration of the prostate such as fluoroquinolones and potentiated sulfonamides has been recommended for any UTI in uncastrated dogs in the past.²⁸ Potentiated sulphonamides were only rarely used in this

cohort. Besides potential unwanted adverse effects such as keratoconjunctivitis sicca or hepatitis,^{67 68} the rare use of potentiated sulfonamides in this study could be due to the limited availability of this class of drugs for companion animals in Switzerland.⁶⁹ The new guidelines for management of UTI issued by the International Society for Companion Animal Infectious Diseases recommend that the prostate has to be evaluated in non-castrated males with UTI. In the absence of evidence of prostatic involvement, it is recommended to treat UTI in non-castrated males as a sporadic UTI.³⁰

The vast majority of dogs with suspicion of UTI that were not treated in accordance with the guidelines were dogs, which received antimicrobial therapy in the absence of bacteriuria on sediment analysis or culture. The reasons for non-adherence were commonly not clear from the medical records. It is imaginable that treatments were started empirically and not discontinued when the sediment or culture result was received or that clinicians disbelieved the results of the sediment analysis but did not follow up with culture.

The tendency to selectively gather and interpret evidence that confirms a suspected diagnosis but ignore the evidences that might disconfirm it (confirmation bias) and risk avoidance have been previously discussed as important elements, which may lead to incoherence between diagnostic test results and clinical decision making in patients with UTI.⁶⁵ Withholding antimicrobial therapy, while providing analgesic treatment, in patients, which can tolerate this approach until a confirmatory test result is received, may reduce the number of unnecessary treatments of UTI.⁶⁵

The group of RTI was diverse and included dogs with kennel cough, aspiration pneumonia and bronchopneumonia. While kennel cough is often a purely clinical diagnosis, a diagnosis of aspiration pneumonia is based on a consistent history and radiographic pattern, whereas a diagnosis of bronchopneumonia should be confirmed via cytological and cultural examination of a BAL sample.⁷⁰ However, in this cohort, 58 per cent dogs were treated on a clinical suspicion of an RTI, and no further diagnostic tests were recorded.

At university hospitals, 54 per cent of RTI cases were hospitalised and in 24 per cent, the clinical signs were judged severe. While this could explain the significantly more frequent use of combination therapy and fluoroquinolones, it could also give an indication to why relatively few bronchoscopies and/or BAL procedures were performed. Indeed, critically ill patients might not be stable enough to undergo general anaesthesia, which is required for bronchoscopy and/or BAL, and tracheal washes, which do not require general anaesthesia, are rarely performed. The use of BAL and antimicrobial susceptibility testing is however crucial to select the most appropriate antimicrobial. A recent study describing sensitivity patterns of bacterial isolates from BAL showed that less than 35 per cent of *Pseudomonas* specie and less than 50 per cent of *E coli* were susceptible to beta-lactam antimicrobials, potentiated

sulfonamides or doxycycline, which are commonly used to treat canine lower respiratory tract infections.⁷¹

While guidelines recommend the use of fluoroquinolones only for severe cases of pneumonia with susceptible organisms,^{70 72} combination therapy using aminopenicillins and fluoroquinolones were commonly used as first-line treatment in the absence of signs of sepsis in this cohort, most likely as a consequence of risk avoidance. In cases with kennel cough, aminopenicillins were commonly prescribed, even though most cases of kennel cough are self-limiting and do not require antimicrobial treatment. If kennel cough is associated with a poor general condition, fever or signs of lower airway involvement, doxycycline is recommended as first-line empirical treatment. Doxycycline is well tolerated by dogs and has good in vitro activity against canine isolates of *Bordetella bronchiseptica*.^{7–9 70 73}

As treatments of uncomplicated wounds and abscesses are rare in referral practice, this indication was only assessed in private practices. In this study, 90 per cent of the dogs presented for abscess or bites were treated with antimicrobials, which corresponds to results of other studies, where the rate of antimicrobial prescription for abscesses and bite wounds was between 90 per cent and 97 per cent.^{19 46} According to guidelines, drainage of abscesses is the most important treatment, and antimicrobials are indicated for bite wounds penetrating the epidermis and for abscesses only in case of fever, reduced general status, highly contaminated wounds or proximity to fragile tissues.^{26 74 75} However, in this cohort, 90 per cent of dogs with abscesses received antimicrobials, while only 39 per cent had an indication. These data, therefore, indicate a large potential for reduction of antimicrobial prescriptions for this indication.

Contrary to other indications, about half of the cases in disagreement with guidelines for WI were because of the non-prescription of antimicrobial although needed. This is in contrast with results from cats in Switzerland and other studies.^{10 12 24}

The limitations of the present study include its retrospective nature and the commonly incomplete documentation of cases in the databases, particularly in private practices, where information regarding history and clinical signs was often not recorded. In this study, practices were only able to participate if they were exclusively using practice management software for their medical record keeping. While vets in Switzerland are obliged to keep medical records, the information was sometimes patchy and difficult to interpret. Moreover, a selection bias could be present. The enrolment of private practices was voluntary, and clinics willing to participate may already be using antimicrobials more prudently leading to an overestimation of the overall adherence to guidelines in the country. Furthermore, the manual review of retrospective data by the two evaluators (CL and KS) possibly leaves a margin of error and judgement errors cannot be ruled out.

Finally, antimicrobial prescriptions were only assessed for four conditions. One important indication for antimicrobial prescription in small animal medicine is pyoderma.^{11 12 14} Given that overuse of systemic

antimicrobials is common for this condition it should be included in future studies.^{37 38}

In conclusion, in 2016, antimicrobial prescription for selected canine diseases showed a poor agreement with national and international guidelines, both at university hospitals and private practices. Antimicrobial stewardship measures are clearly needed to improve prudent use. The impact of the ASP online tool AntibioticScout.ch on prescribing habits of Swiss veterinarians will be assessed in a follow-up study.

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ORCID iDs

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